The influence of soil moisture tension on the fungal population of a pinewood soil

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In an attempt to make a critical evaluation of the effect of soil moisture content on soil mycofloras the concept of pF, as a means of expressing the availability of soil water, has been applied. In both laboratory and field experiments fungi have been isolated from H layer, A_1 and C horizon soil samples taken from a pinewood soil, the soil samples having been held at known pF values. The results indicate that, for all soil samples, the pF range 1.9 to 2.3 (0.08 to 0.2 bar) is optimal for all fungal species, below pF 1.9 (0.08 bar) and above pF 3.8 (6.2 bar) there is a marked reduction in frequency of occurrence of many species. *Trichoderma viride* and *Penicillium* spp. appear capable of growing under a wide range of soil moisture conditions.

Introduction

In many investigations on the water relations of soil microorganisms the amount of water present is given as a percentage of oven-dry soil. Such a presentation does not take into account the energy relations involved in the soil–water–microbe system. However, following the lead of other soil scientists, soil microbiologists are now considering the energy required to be used by microorganisms to obtain water from their substrate, and in doing so are using the concept of pF or the bar notation as a means of expressing the availability of soil water.

The forces within a soil which hold water in it are generally described as "matrix suction" or simply "suction." When freedom of water is further restricted because of osmotic forces (e.g., in saline soils) then the sum of matrix suction and osmotic potential is described as "total moisture potential" (17). In non-saline soils this osmotic factor may not be important unless it is introduced through soil amendments. This may be less serious if the added substrate is only partially soluble or insoluble. However, Mosell and Kuijk (10) have maintained that small changes in the non-aqueous phase of a material (e.g., partial replacement of cellulose by sugar or starch) may strongly influence the relative humidity and thus the moisture potential of the system.

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Schofield (16) proposed that the suction in soil should be expressed as the logarithm of the centimeters of water suction, and introduced the pF scale (pF 0 = 1 cm of water suction, pF 7 = 10^7 cm of water suction). Another method of expressing water suction in soil is the "bar" notation (1 bar = 1022 cm water suction). A summary of the basic concepts involved in applying these ideas to soil ecology has been presented by Griffin (5, 6).

Before systematic investigations on the effect of soil pF on microbial activity were carried out, it was generally held that microbial activities in soil would come to a standstill at pF 4.2 (15.5 bar) (the stage of dryness at which plants wilt). Recent evidence (5) has shown this to be untrue.

Previous work on microbial development and activity in pinewood soils (12, 13, 19) has indicated soil moisture content to be probably the most important factor controlling microbiological activity. It was, therefore, considered necessary to investigate in some detail the water relationships of the fungi in one of these soils. The results of this investigation are presented here.

Materials and Methods

The work described here was carried out on a 'young' soil forming on stabilized sand dunes on the South Lancashire coast. This soil supports a plantation of *Pinus nigra* ssp. *laricio*, the age of the trees being about 40 years old. The soil, described in detail by Parkinson and

Balasooriya (11), is entirely covered with a thick carpet of pine litter which can be differentiated into four distinct layers (L, F_1, F_2, and H).

The parent material of the soil is calcareous sand, but the upper layer has been leached of $CaCO_3$ and is stained with the downwashed products of litter decomposition thus giving an A_1 horizon (up to 10 cm deep). This acid horizon overlies an alkaline C horizon (containing about 2% $CaCO_3$).

For studies on the effect of soil moisture tension on soil fungi, soil samples were taken from the H layer and A_1 and C horizons. During the period of this investigation the soil suction in the field, under natural conditions, fluctuated between pF 1.5 and pF 2.7 (0.03 and 0.5 bar).

Determination of Moisture Characteristics

Before attempting work on the effect of soil pF on soil fungi, it was necessary to determine the moisture characteristics of the soil from the three horizons sampled (H, A_1, and C). To do this soil samples were exposed to suctions in the range pF 0 to pF 5.6 (0 to 389.5 bar), the moisture contents of the soil samples at each pF were ascertained. Graphical representation of these data yielded the moisture characteristic of the soil.

To achieve the range of suction applied to soil samples three different methods were used.

1. Suction plate method (4) was used to achieve pF values in the range 0 to 2.8 (0 to 0.6 bar).

2. Electrical resistance method (1), in which gypsum blocks (in each of which were embedded two electrodes, the blocks being calibrated to show the relation between electrical resistance and moisture tension) were used to measure pF values of drying soil samples. The relation between soil moisture content and soil suction over the range pF 2.8 to pF 4.0 (0.6 to 9.8 bar) was followed.

3. Vapor pressure or relative humidity method. Two methods were applied. In the first of these methods soil samples were allowed to equilibrate above a saturated salt solution of known vapor pressure. Such equilibration was a lengthy process (5 g soil samples at 10°C required 25 weeks to equilibrate). Secondly, to achieve a more rapid drying process a humidity cabinet* was used, and equilibration time was reduced to 7 days in the cases of soil samples from the A_1 and C horizons and to 14 days for samples from the H layer. Using these techniques pF values of 4.7 and 5.6 (4.91 and 389.5 bar) were achieved.

Field Experiments

To dry the soil in the field without causing too much disturbance, an apparatus was designed which consisted of a steel tube (30 cm long, 15 cm diam). The tube had four holes (5 cm × 2.5 cm) which could be covered by caps and through which samples could be taken or gypsum blocks inserted. One end of the tube had a sharp

*Townson & Mercer Ltd., Croydon, England.

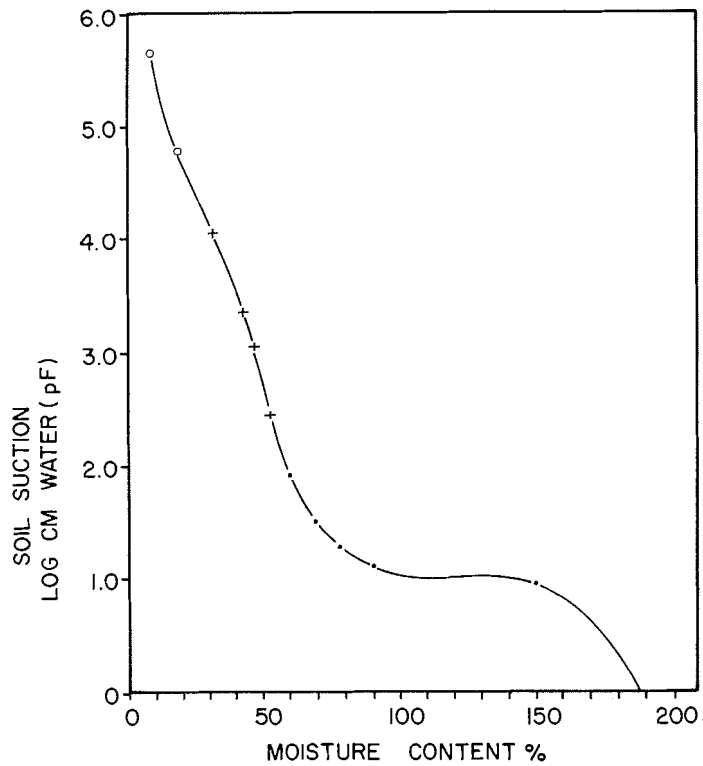

FIG. 1. Soil moisture characteristic for H layer material.

edge to facilitate its insertion into the soil. After insertion into soil the lower end was covered with a cap (placing this cap into position necessitated lifting the tube slightly upwards and removing soil round the tube and just below the lower end; this soil was replaced and pressed down to make the tube firm in the ground). The upper end of the tube was covered with a cap which prevented rain from falling onto the soil contained in the tube; the cap had a downward directed opening to allow evaporation of water from the soil surface.

By inserting calibrated gypsum blocks into the soil core the stage of dryness could be checked by taking resistance readings of the blocks.

This method was not useful for the H layer of the soil because this layer was less than 0.5 cm in depth. Using this method, soil in the A_1 and C horizons was dried over the range pF 2.3 to 4.0 (0.2 to 9.8 bar). Soil samples were taken (for isolation of fungi) using small sterilized glass tubes and the holes provided in the steel tube.

Preparation of Soil Samples in the Laboratory for the Isolation of Fungi

In an attempt to study the effect of soil pF on the fungal populations of the H layer and A_1 and C horizons of the pinewood soil, four replicate samples from each were held at a range of pF values (pF 0 to pF 5.6, i.e., 0 to 389.5 bar). The suction plate method was used to bring soil samples to pF 0, pF 1.0, and pF 1.9 (0, 0.01, and 0.08 bar); the electrical resistance (gypsum block) method to bring soil samples to pF 2.3, pF 2.7, pF 3.8, and pF 4.0 (0.2, 0.5, 6.2, and 9.8 bar), and the relative humidity method to bring soil samples to pF 4.7 and pF 5.6 (49.1 and 389.5 bar).

The soil samples equilibrated at a desired pF were then

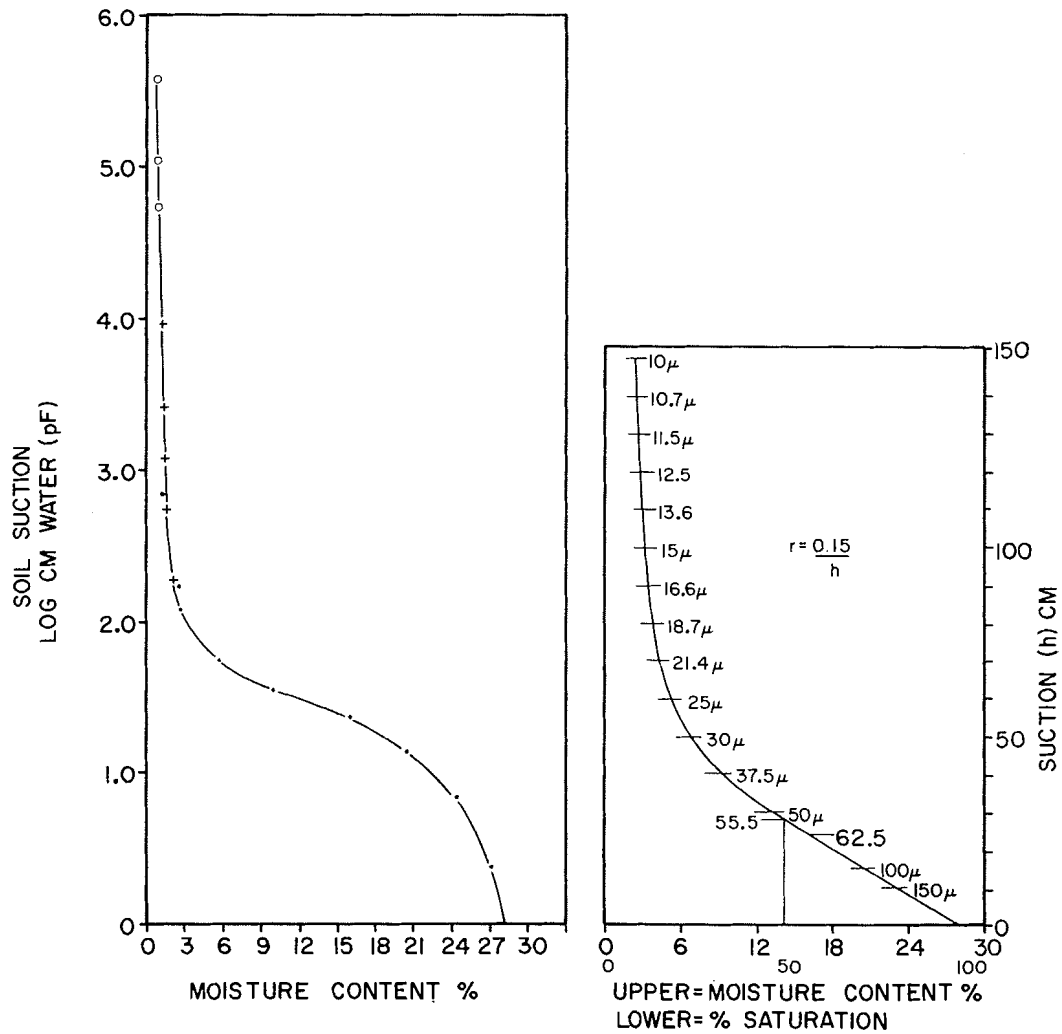

FIG. 2. Relationship between suction and moisture content for the A_1 horizon.

allowed to stand for 48 h at 10°C before isolation of fungi was effected. As pF values greater than 3.0 (ca. 1.0 bar) took 7 days to achieve, the samples at lower pF levels were also held for 7 days under conditions where no evaporation took place.

Isolation of Fungi

The soil-washing technique (14) was used. For the soil under investigation, 30 washings were suitable to remove most of the fungal spores from the H layer and A_1 horizon samples, whilst 10 washings were suitable for C horizon samples.

After washing, mineral particles and organic fragments were plated after excess water had been removed from them using sterile filter paper. Czapek-Dox + yeast extract agar (pH 4.5) was the nutrient medium. Colonies developing on this medium were subcultured and identification attempted.

For spore counts, dilution series were made from the collected washings from individual soil samples. From these dilution plates were prepared in the normal way.

Results

Soil Moisture Characteristics

Figures 1, 2, and 3 show the soil moisture characteristics of the soil investigated. The shape of the curves in the three cases is broadly the same, but there are important differences especially between the H layer and the other two horizons. It can be seen that the water loss from each soil is different at any suction, e.g., at pF 3.0 (ca. 1.0 bar) the C horizon soil has lost 96.8%

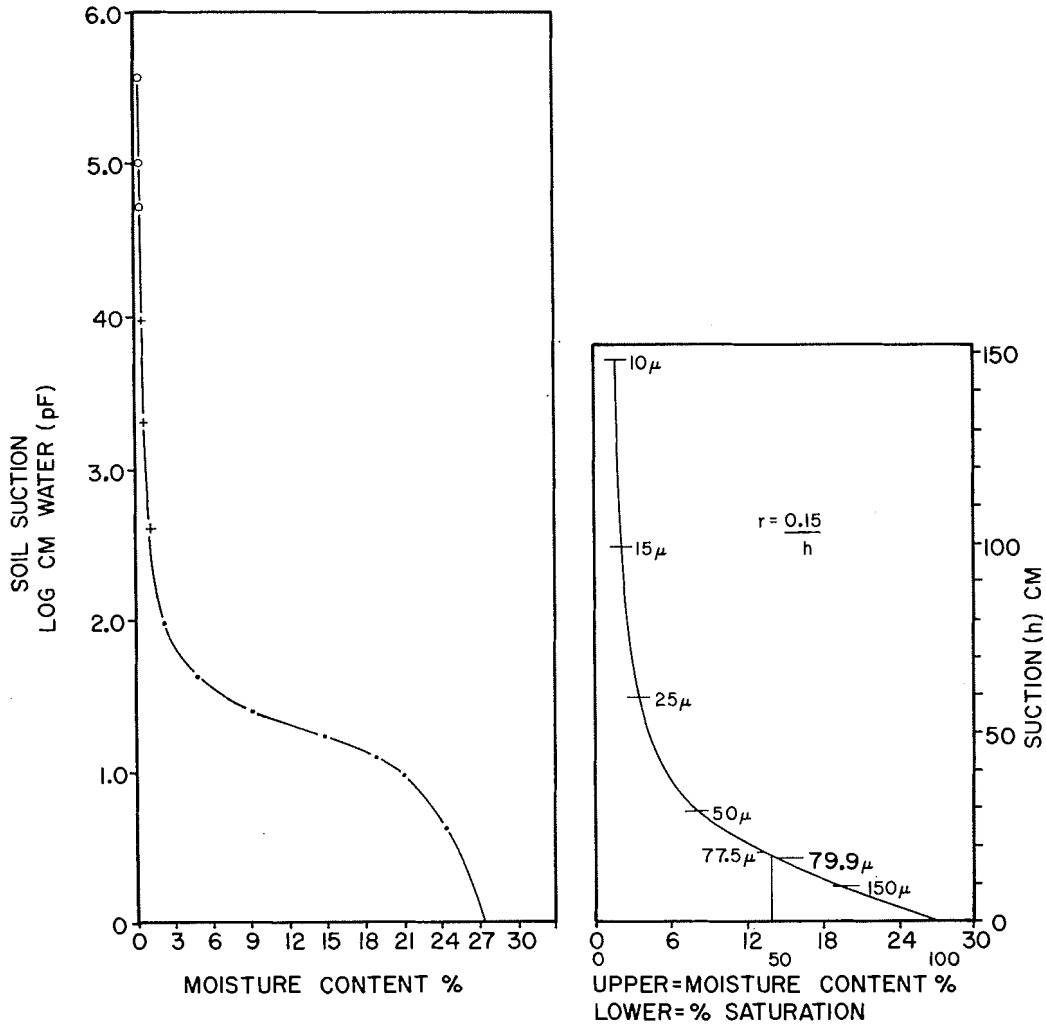

FIG. 3. Relationship between suction and moisture content for the C horizon.

of its total water content, the A_1 horizon soil has lost 95.7%, and the H layer material has lost only 75.2%.

The reason for the greater water retention of the H layer material is that the water is retained in two ways: in the pores and adsorbed to the H layer material (this adsorbed water being released only at higher suctions). In the sandy A_1 and C horizon soils, the water is retained only in the pores (the slight difference between the two horizons may be accounted for by the corresponding difference in organic matter content, i.e. 1.6% in the A_1 horizon, 0.5% in the C horizon, and by a slight difference in the percentage of fine and coarse sand in these horizons).

A characteristic of all soils (including sandy soils) is that relatively little water is released at suctions higher than pF 4.0 (9.8 bar). This is true for the soils studied in these experiments.

Information on the pore size distribution in soil can be obtained from the curves relating suction and moisture content (3, 8). Using the formula

$$r = 2s/d.g.h$$

(at 20°C, $2s/d.g = 0.15$)

r = equivalent radius of pore neck in centimeters (equivalent because the pore neck will not be circular),
d = density of water,
g = gravitational constant,
h = cm water suction,
s = surface tension of water,

and a linear representation of the suction–moisture content curve, calculation of pore size distribution throughout the pF can be made (Figs. 2 and 3) and also whether pores of a particular size are full, empty, or partly filled with water at any given suction.

In the A_1 horizon soil it can be seen (Fig. 2) that 50% of the pore volume consists of pores larger than 55.0 μ. Similar calculated data for the C horizon (Fig. 3) indicates 50% of the pore volume to consist of pores larger than 78 μ. Thus the representative pore sizes in both these horizons provide suitable conditions for fungal sporulations, and it can be said that pores of this size order would be emptied at a suction of about pF 1.7 (0.04 bar).

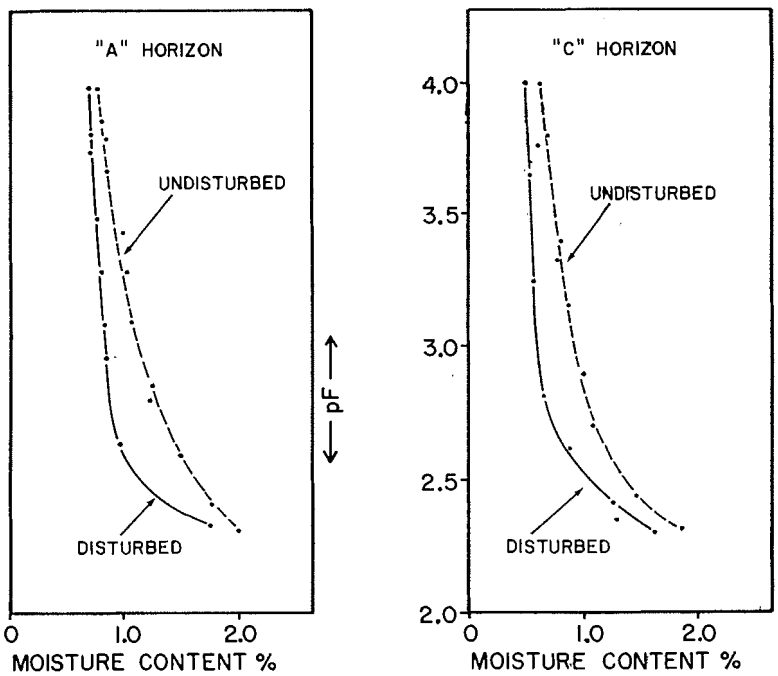

FIG. 4. Soil moisture characteristics determined on disturbed and undisturbed samples of A_1 and C horizon soil.

These calculations are based on the assumption that there will be no change in the volume of the soil while water is released when a suction is applied. Even though shrinkage in the H layer

TABLE 1

Fungi isolated from the Freshfield soil (by the soil-washing technique)

Fungi isolated	Horizon H	Horizon A	Horizon C
Absidia coerulea Bainier.	+++	++	−
Mortierella parvispora Linn.	++++	+++*	−
M. pusilla Oudemans.	+++	++*	−
M. isabellina (Oudemans) Zycha.	+++	+++	−
M. vinacea Dixon-Stewart	−	+++	+++
M. alpina Oudemans.	−	−	++*
M. marburgensis Linn.	+	+*	−
Mucor hiemalis Wehmer.	+++	++*	−
Rhizopus nigricans Ehrenberg	+	+	−
Gelasinospora retispora Cain.	++++	+++	−
Sordaria fimicola (Rob) Cos. & DeNot.	+	+	−
Cladosporium sp.	−	+++	+
Trichoderma viride Pers.	+++++++	++++++	+++
Penicillium decumbens Thom.	+	+++	+++++++
P. cyclopium Westling.	++	+++	+
P. montanense Christensen & Backus	+	++++	−
P. lividum Thom.	+++	++	−
P. citrinum Thom.	+++	++	−
P. corylophilum Dierck.	+	+++	−
Penicillium spp.	+++	++	++
Oidiodendron fuscum Ropak	−	+++	+
Cylindrocarpon destructans (Zins.) Scholten	−	++	++++
Verticillium nigrescens Pethybr.	−	−	+
Giliomastix sp.	−	+++	+
G. convoluta (Harz) Mason	−	−	+
Dicoccum asperum Corda.	+++	+*	−
Phialophora fastigiata (Launderberg & Melin)	−	−	++
Phoma sp.	+++	+++	+++
Sterile dark No. 1	++	++*	−
Sterile dark No. 2	+	++	−
Sterile dark No. 3	−	++	+
Sterile dark No. 4	−	++*	−
Sterile dark No. 5	−	−	++*
Sterile dark No. 6	+	++*	−

*Species restricted to organic fragments.

NOTE: % frequency is as follows: + = 1, ++ = 1–10, +++ = 11–20, ++++ = 21–30, +++++ = 31–40, ++++++ = 41–50.

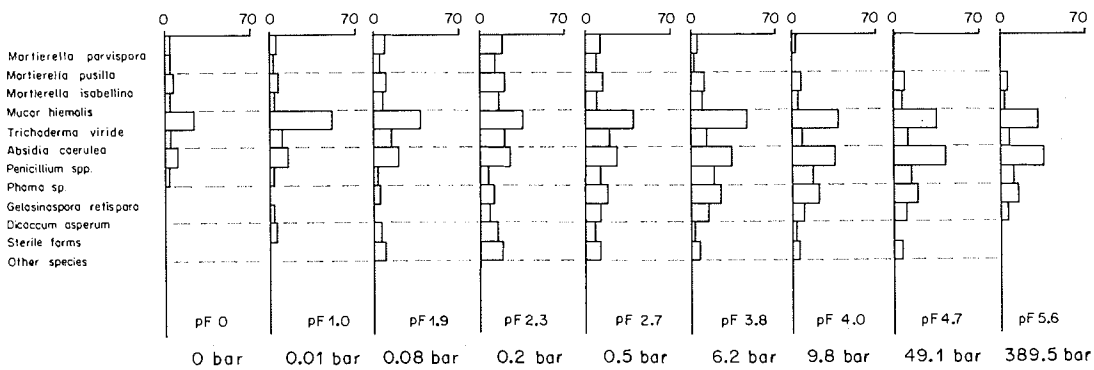

FIG. 5. Occurrence of fungi in H layer samples maintained at known pF values (occurrence indicated as % particles colonized).

was slight, it was considered inadvisable to apply the equation ($r = 0.15/h$) to calculate pore size.

As stated earlier, moisture characteristics were also determined under field conditions over the range pF 2.3 to pF 4.0 (0.2 to 9.8 bar). For the purpose of comparison an equivalent portion of the moisture content – suction curve determined in the laboratory has been redrawn (Fig. 4).

From this figure it can be seen that both A_1 and C soils retained more water when dried under field conditions than when dried in the laboratory (where the soil samples were subject to considerable mechanical disturbance). Salter and Williams (15), working on widely different soils, noted similar but larger differences.

Behavior of Soil Mycoflora at Different Soil Suctions

Table 1 gives data on fungi isolated (by the soil washing technique) from fresh samples of soil from the H layer, A_1 and C horizons of the soil under study.

Laboratory Experiments with Different Soil Suctions

Details of the behavior of fungi at different soil moisture tensions, as indicated by their percentage frequency of occurrence on washed soil particles, are given in Figs. 5 to 7. It can be seen from these data that, generally speaking, the experimental range of pF values (0 to 5.6, i.e., 0 to 389.5 bar) does not limit the survival of many fungi in the soil under experiment. Waterlogged conditions appear to inhibit fungal growth more than drought does. The results show that Phycomycetes are the most sensitive of all the species present in the soil to higher soil suctions. In contrast, *Gelasinospora retispora*, *Dicoccum asperum*, *Phoma* sp., *Trichoderma viride*, and *Penicillium* spp. are the least sensitive to drier conditions. Phycomycetes also appear intolerant of waterlogged soil conditions

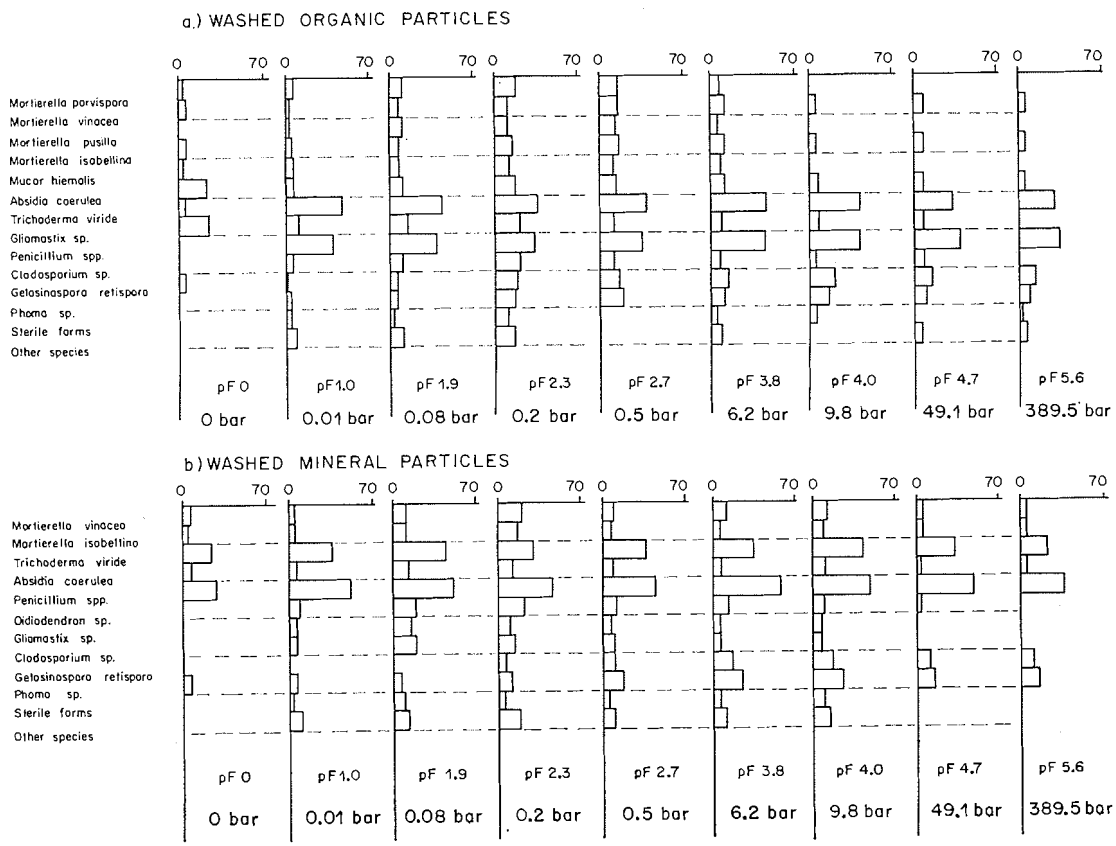

FIG. 6. Occurrence of fungi in A horizon samples maintained at known pF values (occurrence indicated as % particles colonized).

(pF 0), as do *Gelasinospora*, *Dicoccum*, and *Phoma*.

Trichoderma and *Penicillium* spp. appear to be capable of growing under a wide range of soil moisture conditions. This may be one explanation for their frequent occurrence in species lists of fungi isolated from many parts of the world. *Phoma* sp. also appears to be tolerant of a wide range of soil moisture conditions, but, perhaps because its spores are few in number and germinate relatively slowly, it always formed a small proportion of the isolates, never exceeding *Penicillium* spp. and *Trichoderma* in frequency of occurrence.

For all soil horizons studied it would appear that the pF range 1.9–2.3 (0.08–0.2 bar) seems to be optimal for all species. Below pF 1.9 (presumably because of decrease in oxygen and increase in CO_2) there is a marked reduction in fungal occurrence, while above pF 2.3 (0.2 bar) there is a gradual decrease in numbers of species isolated and in the frequency of occurrence of most isolated forms, until at pF values above 3.8 (6.2 bar) this reduction becomes marked.

Field Experiments

In these experiments the soil of the A_1 and C horizons were dried without causing much disturbance. As can be seen in Table 2 some species showed increased tolerance to various suctions (within the range pF 2.3–4.0, i.e., 0.2–9.8 bar) as compared with their behavior in laboratory experiments at the same suctions.

A good comparison can be made in percentage frequency of fungi at pF 4.0 (9.8 bar). Here at least three species disappeared and the rest showed reduced frequency of occurrence in the laboratory experiments in comparison with their behavior in the field experiments.

Time Factor

During laboratory experiments, pF values of 4.7 and 5.6 (49.1 and 389.5 bar) were achieved in two ways: in the conventional sealed jars (which require 25 weeks to achieve the desired moisture status) and in the humidity cabinet (where the desired moisture status is achieved in 1–2 weeks).

Table 3 gives data on fungi isolated from soil samples dried to required pF by each of the methods. It can be seen from these data that in soils dried in sealed containers the fungus flora was reduced to a few organisms (*T. viride*, *G. retispora*, *D. asperum*, *Phoma* sp., and *Penicil-*

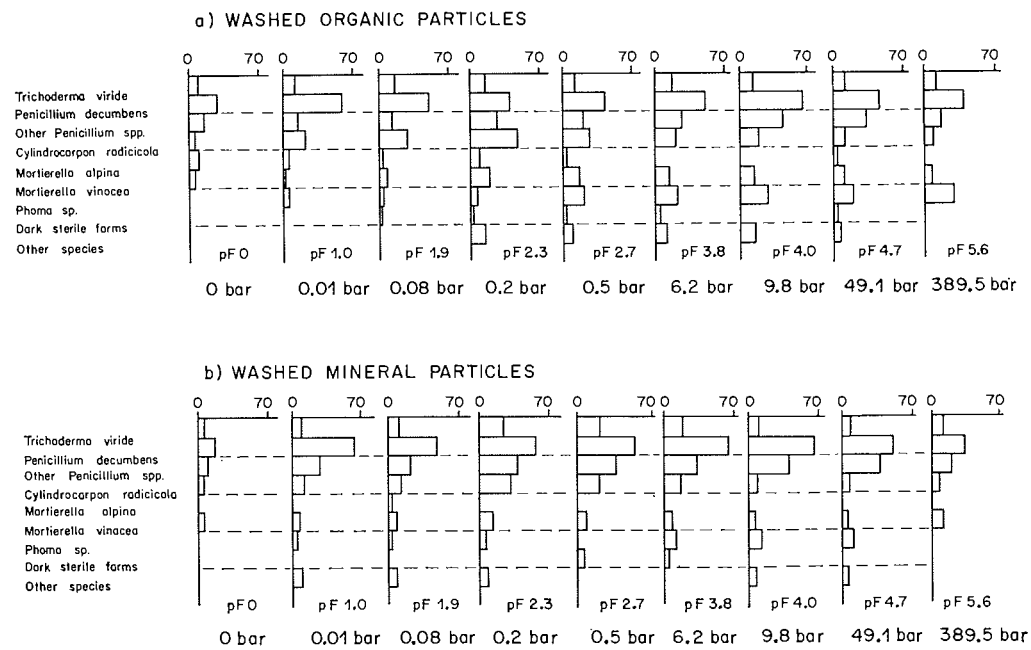

FIG. 7. Occurrence of fungi in C horizon samples maintained at different pF values (occurrence indicated as % particles colonized). [NOTE: In both *a* and *b*, *Cylindrocarpon radicicola* should read *Cylindrocarpon destructans*.]

TABLE 2

Fungi showing increased tolerance to pF conditions in "undisturbed" soils
(Figures represent % of particles colonized, those figures in parentheses indicate data in disturbed soil samples of A_1 and C horizon soil dealt with in the laboratory)

Fungi	pF 2.3 (0.2 bar)	pF 2.7 (0.5 bar)	pF 3.8 (6.2 bar)	pF 4.0 (9.8 bar)
Absidia coerulea	18.5 (15.0)	13.5 (11.0)	10.5 (9.8)	8.0 (5.0)
Mortierella parvispora	21.5 (17.0)	17.5 (11.5)	9.0 (4.7)	5.0 (0.0)
M. pusilla	14.5 (11.0)	10.5 (9.0)	6.5 (3.8)	4.5 (0.0)
M. alpina	12.0 (9.5)	8.5 (5.0)	5.0 (1.5)	3.0 (0.0)
Mucor hiemalis	15.0 (10.0)	11.5 (7.5)	8.0 (5.5)	5.0 (1.5)
Cylindrocarpon destructans	45.0 (42.5)	30.5 (23.0)	22.0 (19.0)	17.5 (15.0)
Gliomastix sp.	22.0 (19.5)	12.5 (9.0)	10.0 (8.5)	7.5 (5.0)
Cladosporium sp.	20.5 (17.5)	11.5 (8.5)	9.0 (5.0)	5.5 (3.0)

TABLE 3

Effect of equilibration time on selected fungi
(Figures indicate % frequency of occurrence of individual species)

	Equilibration time			
	25 weeks (sealed containers)		1–2 weeks (humidity cabinet)	
	pF 4.7 (49.1 bar)	pF 5.6 (389.5 bar)	pF 4.7 (49.1 bar)	pF 5.6 (389.5 bar)
Absidia coerulea	0	0	5.7	2.5
Mortierella vinacea	0	0	7.5	3.0
M. isabellina	0	0	5.6	2.9
Mucor hiemalis	0	0	5.0	2.0
Gelasinospora retispora	10.0	6.5	11.6	9.0
Cylindrocarpon destructans	0	0	9.5	4.0
Penicillium decumbens	30.0	21.0	46.5	32.0
Phoma sp.	9.0	6.0	12.5	11.0
Trichoderma viride	29.5	15.0	35.0	26.0

TABLE 4

Spore content of soil samples from the H layer, A_1 and C horizons held at different suctions (recorded as fungal colonies per gram dry weight on soil appearing on soil dilution plates)
(Figures in parentheses are fungal counts for soils dried in the field)

pF	0	1.0	1.9	2.3	2.7	3.8	4.0	4.7	5.6
bar	0	0.01	0.08	0.2	0.5	6.2	9.8	49.1	389.5
H layer	900	14 000	99 900	702 000	96 200	79 500	75 500	19 800	9600
A_1 horizon	500	8 000	23 500	25 000 (20 300)	19 000 (14 200)	17 000	13 600	9 500	6300
C horizon	300	6 700	20 000	22 000 (18 700)	17 000 (12 000)	14 100	9 900	2 500	1000

TABLE 5

Effect of equilibration time on fungal spore numbers in soil samples from the H layer and A_1 and C horizons
(recorded as fungal colonies per gram dry wt. of soil appearing on soil dilution plates)

	pF 4.7 (49.1 bar)		pF 5.6 (389.5 bar)	
	1–2 weeks (humidity cabinet)	25 weeks (sealed containers)	1–2 weeks (humidity cabinet)	25 weeks (sealed containers)
H layer	19 800	9600	9586	1488
A_1 horizon	9 500	2000	6256	950
C horizon	2 500	730	996	250

lium spp.). But for soil dried relatively rapidly in the humidity cabinet more species were isolated and the above mentioned species were more abundant.

Spore Count at Different Suctions

The soil dilution plate technique (a technique known to be 'selective' for fungal spores in soil samples) was applied, using the washing water from the soil-washing technique. The data obtained from soil samples held at known pF values under laboratory conditions are given in Table 4.

The significant difference in fungal populations observed in soil samples dried in a humidity cabinet (1–2 weeks) as compared with soil samples dried in sealed containers (25 weeks) was also evident in the fungal spore counts from soil dried in the two ways (Table 5).

From the results given in Table 4 it can be seen that the lowest number of spores was recorded in soil samples held at pF 0. In the range pF 1.9–4.1 (0.08–12.3 bar) large numbers of viable spores were present in the soil samples (the fungi developing on these dilution plates belonged to heavily sporing or fast-growing genera). The effect of decreasing soil moisture was much less than the effect of waterlogging.

Discussion

This investigation gives an indication of the importance of taking the energy concept of soil moisture into account when one is studying the relation of soil water to fungal distribution and activity. The data provided clearly illustrate that soil moisture – energy relation (energy of retention) is a continuous function and varies from soil to soil and even from horizon to horizon within a profile. If results for soil water are expressed as percentage moisture many erroneous conclusions may be drawn because the availability of water for microorganisms does not correspond to the water content as such, but to the suction force necessary to maintain the required extraction rate. However to say that an organism is active under precise pF conditions indicates the force being exerted to obtain water from the environment. Thus, in the soil studied here, microorganisms must exert the same force to obtain water from the H layer containing 57% water as they do to obtain water from the A_1 horizon containing 3% water.

The calculated pore size distribution for A_1 and C horizon soils affords additional information on the space available for fungal development and sporulation. The radii of pore necks of the representative pores in these soils were about 62 μ (A_1 horizon) and 80 μ (C horizon). Pores of this order of size will remain full of water at about pF 1.3 (0.02 bar), will begin to drain above this pF value and may be emptied of water at about pF 1.7 (0.04 bar). This may explain why the overall growth response of fungi was better at pF 1.9 (0.08 bar) than at pF 0 or pF 1.0 (0.01 bar).

On the basis of the data presented, the basic fungus population of the soil studied here can be divided into three distinct groups based on their reaction to soil moisture tension. The first group, comprising *Mortierella parvispora*, *Mortierella pusilla*, *Mortierella alpina*, and sterile dark forms, are extremely sensitive to higher soil suctions. The second group, including *Mortierella isabellina*, *Mortierella vinacea*, *Mucor hiemalis*, *Cylindrocarpon destructans*, *Cladosporium* sp. *dia coerulea*, and *Oidiodendron* sp. may be considered to be fairly tolerant of higher soil suctions. The third group, comprising *Trichoderma viride*, *Phoma* sp., *Penicillium decumbens*, other *Penicillium* spp., *Dicoccum asperum*, and *Gelasinospora retispora* appear almost insensitive to higher suctions. If the classification based on the minimum and maximum relative humidity requirement for the growth of fungi, as proposed by Walter (17), Heintzler (6), and cited by Griffin (5) can be applied for ecological differentiation, then roughly speaking the abovementioned first group may be classed as hygrophiles, the second as mesophiles, and the third as xerophiles.

The further distinction in the soil mycoflora can be made on the ability of different organisms to grow in water-saturated soils. *T. viride*, *Phoma* sp., *Penicillium* spp., *Gliomastix* sp., and *C. destructans* were found to be less sensitive to waterlogged conditions than were other fungi. No attempt was made in this investigation to establish the degree of anaerobiosis in the soils at pF 0. Miller and Johnson (8) reported 4–6% porosity at pF 0 in two of the three soils they studied.

Burges (2) pointed out that ecologists were neglecting the time factor in their studies. The effect of the time factor in the present investiga-

tion has been shown, in the comparison between the two methods for achieving pF values of 4.7 and 5.6 (49.1 and 389.5 bar). Here the conventional sealed jars required 25 weeks to achieve equilibrium while with a humidity cabinet only 1–2 weeks were required. Using sealed jars, the soil mycoflora was reduced to a few species (*T. viride*, *G. retispora*, *D. asperum*, *Phoma* sp., and *Penicillium* spp.), but in soils dried in the humidity cabinet not only were the abovementioned genera more abundant, but other organisms appeared able to tolerate these higher soil suctions. Thus the use of long-term drying in sealed jars may lead to serious errors. Besides extending the time period to which microorganisms are subjected to dry conditions, it also leads to the unwanted accumulation of CO_2 in the sealed jars, a phenomenon which, when coupled with drought conditions, could kill a large proportion of the fungal population.

Laboratory experiments in soil microbiology are frequently criticized on the grounds that natural environments have been subjected to gross, irreparable disturbance. In the experimental work reported here data have been obtained from soil samples held in the laboratory and from soil cores localized but maintained in the field. Differences have been recorded between the sets of data obtained from these two groups of soil samples, it being found that some organisms which showed sensitivity to a particular moisture stress in the laboratory could tolerate the same soil suction under natural conditions. This is probably due to the fact that in the laboratory-held samples the soil underwent drying twice, the air-drying after sampling and the drying after saturation with water to bring the soil to a known pF status. This double drying in laboratory experiments was inevitable because it was impossible to wet the soil samples and also attain uniform moisture distribution in the samples without first drying them.

The data obtained from applying the soil dilution plate method gives data on numbers of viable spores in the soil samples at different soil moisture tensions. These data show reduction in numbers at the extremes of moisture status. The numbers of colonies of heavy-sporing fungi, such as *T. viride* and *Penicillium* spp., which also appeared to be less sensitive to increasing pF, were found to mask the effect of higher matrix suction on other fungi which may be actively participating in soil processes. This fact may explain previous reports showing a lack of correlation between soil moisture and fungal "numbers."

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